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ABSTRACT

This paper examines the effects of learning time on student achievement. It begins by reviewing what is known about how time is allocated and utilized in schools and the effects of differing amounts of exposure to schooling on achievement. Several theoretical perspectives concerning how time spent affects achievement are briefly discussed. The central focus of the paper is the development of a teacher/learner/task model of the production of learning. Incorporated into this model are three factors: task structure, nonlinear effects, and task organization. Several experiments that use this model in a computer simulation are described. These studied how variations in task structure, pacing of teaching and learning, and timing of teaching and nonteaching intervals affect achievement. The experiments suggest that different teaching strategies are required for learning tasks of different structure, that teaching strategies for producing the maximum average classroom achievement and a minimum level of competence are not the same, and that the timing of teaching and nonteaching intervals alter the effectiveness of teacher and learner. One section of the paper explains the concept of a time scale and its usefulness. A discussion and summary section containing suggestions for future research concludes the paper. (Author/JM)

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The Organization of Time in Schools: Time Scales and Learning

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1. Introduction

Currently, by the time a student graduates from high school he will have spent around 12,000 hours in school. What is most surprising about this fact is how little is known about how those 12,000 hours are spent. What the student actually does during those many hours and the consequences for learning is understood only dimly. We have little knowledge, apparently, about how time is spent in school or what the learning consequences are of spending differing amounts of time or of spending the same amount of time in different ways.

This lack of knowledge has recently been recognized by several commentators and presently there is a burgeoning research interest in the area of time and learning. The evidence to date from these efforts has not provided consistent, generalizable effects of time spent and learning gained.

This paper suggests that several aspects of the learning setting which have not been incorporated in these studies may contribute to the meagerness of the research results. In particular, we suggest three factors which may be potentially important determiners of how time spent affects learning outcomes.

First, most studies have assumed that learning and time are linearly related. This assumption implies that more time in school will produce a corresponding increment in achievement. The non-sensitivity of many empirical studies to non-linear effects may have hidden or distorted existing time effects.

Second, existing studies have often not paid attention to the im-

portance of task structure in examining time effects. The nature of the task to be learned is seen as tempering how time spent affects achievement gained. The level of difficulty of the task and the extent of inter-relatedness of this task with other learning tasks are suggested as two particularly important features of task structure which will alter the effect of time spent.

Third, the question most often addressed in these studies has been: what is the effect of time spent on achievement gained? Because the same amount of instructional time can be organized in numerous different ways, we see the more interesting question to be: how does the organization of time spent affect learning outcomes? By the organization of time we refer to the way the instruction is packaged, including such controllable features as the rate of teaching or the timing of breaks and such uncontrollable ones as the timing of interruptions and of boredom or fatigue.

The effect of these factors--non-linearity, task structure and packaging--are considered explicitly in this paper. Their effects are incorporated into a model of how teachers and learners, involved in a particular learning task produce learning. This model is operationalized by a computer simulation with which we carry out different learning and teaching "experiments." These experiments are used to demonstrate how dramatic achievement effects can come about as the result of consideration of non-linear effects, task structure effects and packaging effects.

The first theme of this paper then is that time effects on learning are likely to be more complicated than presently entertained. A second theme is that despite such complexity, the relationships among the variables can be investigated in terms of a single metric - their time scales. By a time scale we mean the amount of time needed for the process of interest to be completed. This notion of a time scale is suggested as an extremely useful one for it simplifies both several conceptual and methodological considerations. First, we point out that the knowledge of the relative magnitudes of time scales is required to make reasonable decisions about how much time to allocate to schooling and how that time might be productively organized. Second, recognition that variables and their relationships can be expressed in terms of their time scales provides a common denominator, e.g. time, for comparing and assessing effects.

The paper begins by describing what is known about how time is allocated and utilized in schools and the effects of differing amounts of exposure to schooling on achievement (section 2). Several theoretical perspectives which suggest how time spent affects achievement are briefly discussed in section 3. In commenting on these perspectives, we note that features of the learning setting which are of particular interest here are not systematically addressed in any one perspective.

The central focus of this paper is the development of a

teacher/learner/task model (TLT) of the production of learning, the topic of section four. The TLT model views learning as a process in time whose parameters can all be expressed in terms of time. This model is operationalized as a computer simulation. Using this simulation, several experiments are carried out to study how variations in the structure of the learning task, the pacing of teaching and learning and the timing of teaching and non-teaching intervals affect achievement outcomes. These experiments suggest that quite different teaching strategies (rates) are required to produce maximum achievement for learning tasks of different structure. In addition, quite different teaching strategies are required for producing the maximum average classroom achievement and for producing some minimum level of competence. Finally, these experiments document that the timing of teaching and non-teaching intervals (e.g. interruptions and recovery from interruptions) alters the effectiveness of teacher and learner.

Section five elaborates the idea of a time scale and how it may serve as a unifying notion for conceptualizing and measuring the effects of time on learning. The discussion and summary presented in section six suggest some contributions of the present paper and some additional research activities.

2. Time and Schooling

An interest in how schools use time is not new. The scientific management movement in the early 1900's included various efficiency studies of the use of time in schools that pressed for the productive use of time. As Thompson (1915, p. 29) records in his summary of these efforts, "The teacher is thought of as immoral if he wastes time or permits it to be wasted." Unfortunately, as Callahan (1962) remarks in Education and the Cult of Efficiency, the scientific management movement often resulted in the indiscriminate adoption and application of practices without consideration of their educational value or purpose. Thus, emphasis was placed on "producing the lowest costs," not on "producing the finest product" (p. 244).

Current interest in the use of time in schools has been fueled by the discontent with declining standardized achievement test scores and by the demand for teachers and schools to be held accountable for their performance in producing basic student skills. The present interest in how the use of school time affects achievement can also be understood as a logical consequence of the decade long documentation of "no school effects" following the findings of the Coleman Report (Coleman et al., 1966). This report found that the differences in resources among schools were not that large and as such were relatively unimportant factors in explaining school to school differences in student achievement. Numerous studies have criticized, reanalyzed and debated the conclusions of this report, but to date its basic findings have not been denied.

The recent interest in quantitative effects, then, comes both from a thrust to make schools more productive and efficient and from a concern with documenting how differences in schooling affect achievement. The next section discusses the current evidence concerning differences in the allocation of time to schooling and differences in the utilization of the allotted time, and reviews studies of whether more time in school does make a difference for student outcomes.

Allocation of Time to School

State and other legislation require school attendance between certain ages, for a certain number of days per year and for a certain minimum amount of time per day. Over the last one hundred years, the amount of time actually allocated to schooling has increased dramatically.

The universality of compulsory schooling and its extension to a wider age range has contributed greatly to the overall increase. Compulsory schooling between certain ages determines the framework of current school organization practices, the keystone of which is the division of learners into age homogeneous grades. If compulsory schooling were organized by some other principle than age attainment--for example, by mastery level--grouping criteria would necessarily differ. If attendance were required until mastery, groups would cluster around attainment levels, and classes would then be age heterogeneous; six-year-olds and ten-year-olds might be learning the same skill. Not only would the composition of classes be more varied, the ages of completion of the required mastery would also be more variable. Changes in school-leaving age would

dramatically alter the timing of entrance into other life events which are expected now to occur after completion of schooling. The meaning of entrance into the labor market, assumption of marriage, beginning of a family--all events viewed as happening after completion of schooling--would be affected by altering the age-graded nature of schooling. Indeed, the contemplation of the effect of such a change makes clear how the temporal organization of people's lives is predicated on compulsory schooling to a specific age.

There is, in every state except Mississippi, a legal age at which schooling must begin and through which schooling must continue. For example, Alabama requires compulsory attendance between ages 7 and 15; Hawaii between ages 6 and 18. Such differences in the legal requirements for schooling are not typically recognized. Nor is it commonly appreciated that within the permissive starting and staying ages, striking variations in enrollment patterns exist. For example, both Colorado and Alabama mandate that schooling begin by age 7, but attendance before that age is permissable. In Alabama 29 percent of all six-year-olds were not enrolled in school in 1970; in Colorado, only 4.7 percent were not enrolled (Children's Defense Fund, 1974).

This quick look at some conditions of compulsory years of schooling suggests that it is a major source of variation in exposure to schooling. Another potentially important factor is the number of days per school year. The length of the school year has increased considerably over the last 100 years. In 1869 the average school year was 132.2 days; presently it is around 179 days (Statistics of State School Systems 1971-1972, Table 22, p. 45). The length of the school year, although increasing over this period, did show considerable variation among regions of the

country, urban and rural areas, and racial groups. In 1930, for example, students in the south attended 147 days per year while northerners and westerners attended 177 days per year. Rural students in the north and west attended 175 days per year while urban students attended 181 days per year (Meyer 1977, Table 6). At present, states still legislate a differing number of school days, ranging from 175 to 184; even within a state the number of school days in session per year may vary. In Maryland, for example, in 1975-76, some school systems were open 180 days while others were open 185 days. There is a legal minimum number of days; school districts may optionally exceed that minimum.

Other factors that determine the number of operating days in a school year are teachers' strikes and early school closings due to financial or fuel shortages. Despite the prevalence of these events, no one has systematically evaluated the extent to which and with what educational consequences school terms have been shortened by these incidents.

Little data exist on the length of school days. Mann (1928) found that in 1926 the length of the elementary school day ranged from 240 to 420 minutes in the 444 cities he studied. In comparing the length of the school day over the period 1823-1926, Mann found that the general trend was to reduce the length of the school day. For example, the length of day for first graders was reduced by 106 minutes per day over this period. However, the school term was lengthened greatly. At present, the length of the school day may vary appreciably through such scheduling practices as double shifts. One report (Reuter, 1963) claims variation in school day of between 4 and 6 hours. The length of school day for all public elementary schools in the state of Maryland shows considerable variation

across counties (school districts) and even within school districts. The minutes per day for elementary schools range from 240 to 410. This extent of variation within one state is surprising, given the assumed uniformity of elementary school organization. The length of day for public junior and senior high schools within a county are also variable. In one Maryland county the range of school day for high schools was 300 to 375 minutes. In addition to these already existing differences, the school day within the same county may be organized differently, some schools having seven 50-minute classes with five minutes in between, others having eight 45- minute classes with three minutes in between. These organizational patterns are important, especially if there is appreciable "start up" and "wind down" time associated with any class period.[1]

This brief and incomplete survey suggests that schools are not uniform in their time allocation. Opportunities for schooling determined by compulsory school ages, length of school term and length of school day vary greatly from place to place and from time to time. How these opportunities are utilized is the subject of the next section.

Utilization of Time in School

Compulsory schooling legislation mandates starting and minimum school leaving ages. There are also permissive starting and leaving ages for which free education is supplied. Attending school during these optional attendance ages is another means by which significant variation in length of school exposure occurs. (A less obvious way in which non-mandatory "schooling" experiences have been extended to an earlier age

is through formal day care. Day care experiences for two-to-five year olds, although not usually viewed as schooling, serve important socialization functions. Youngsters are familiarized with group settings and procedures, and with schedules and rules, which are important pre-requisites for later learning in the group-based formal school situation. The school day has also been extended in many cases to include after school care for children of working mothers.)

Perhaps the most publicized way in which opportunities for learning are reduced is through absences from school. Table 2.1 shows the percentage of enrolled students attending daily, and the average number of days attended by each student enrolled, for the period 1869-1970. School attendance on the average has increased dramatically over the period. However, there are currently very great variations in daily school attendance, depending upon the region and urbanity of the school

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Table 2.1 Here

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system. For example, large urban school districts systematically report lower attendance rates than their suburban counterparts. In 1975 Baltimore City reported an average daily attendance of 85.2 percent; in surrounding Baltimore County it was 93.9 percent. Students vary a great deal in the extent of unexcused or questionable absences, depending upon their age, sex, race, school involvement, motivation, and opportunities for truancy (Karweit, 1973; Levanto, 1973). For many students, the drawing power of the schools is weak compared to outside of school events. This factor, coupled with the schools' lack of effective sanctions in dealing with truants, has contributed to the upward trend in the

YEAR	Percentage of enrolled pupils attending daily	Average length of school term (in days)	Average number of days attended by each pupil enrolled
1869 - 1870	59.3	132.2	78.4
1879 - 1880	62.3	130.3	81.1
1889 - 1890	64.1	134.7	86.3
1899 - 1900	68.6	144.3	99.0
1909 - 1910	72.1	157.5	113.0
1919 - 1920	74.8	161.9	121.2
1929 - 1930	82.8	172.7	143.0
1939 - 1940	86.7	175.0	151.7
1949 - 1950	88.7	177.9	157.9
1959 - 1960	90.0	178.0	160.2
1969 - 1970	90.4	178.9	161.7

Table 2.1

Average Daily Attendance 1869-1970

Source: U.S. Department of Health, Education, and Welfare. National Center for Education Statistics. Statistics of State School Systems 1971-1972, Table 22, p. 45.

absentee problem (which has become truly legendary in some school settings). Nonetheless, imaginative and resourceful use of positive treatments (peer support and material incentives for good attendance), coupled with definite and known negative consequences (e.g. day-time curfews) are being implemented in some areas and appear effective.[2]

School absence accounts for a large proportion of the schools' and students' failure to use allocated time for instruction. However, once the student is in school, a large proportion of the in-school time may be taken up with procedural or other non-learning activities. Cusick (1973) found that over 200 minutes of the school day in one high school was spent on procedural or maintenance tasks. He summarized the school routine by stating that "the time spent actively engaged with some teacher over a matter of cognitive importance, may not exceed twenty minutes a period for five periods a day. This is a high estimate. I would say that if an average student spent an hour to one and a half-hours involved in subject matter--that was a good day." (p. 56)

Few studies have documented how classrooms differ within and across schools in the time spent on procedural vs. cognitive tasks. A recent study of 6 kindergarten classrooms in Baltimore (Berkeley, 1978) determined that the percent of time in cognitive tasks ranged from 17.8 to 36.9. Procedural activities, such as lining up, occupied a range of time from 33.1 percent to 60.5 percent of the available school time. Classroom interruptions, such as the lateness of the teacher to class, or the teacher being called out of class, took up 2 percent to 16 percent. Berkeley's study documents that the utilization of available time for cognitive tasks is highly dependent on the particular classroom/teacher setting.

Frederick (1977) in a comparison of time use in 27 Chicago public high schools found significant differences in time utilization between schools classified as low achieving and high achieving. Observing 184 classrooms and documenting incidents of inattention, disruption and absence, he found 25 percent of the allotted time in the high achieving schools concerned with these events, compared to 49% in the lower achieving schools.

These studies support the assertion that traditional schooling practices involve the child for only a small fraction of the school day. In many classrooms, much of the instructional time may be consumed with interruptions, distractions, discipline and other non-instructional activities.

Given that the teacher is engaged in actual teaching, students no doubt vary a great deal in the percent of time that they are actively engaged in learning. For example, Frederick (1977) found that the higher achieving schools were characterized by higher rates of involvement in learning (92%) than the lower achieving schools (84%). Bloom (1976) found that some students spent up to three times as much time in active learning as others during the same length of elapsed time. Engagement time would seem to depend on many factors, including disposition, motivation, ability and prior knowledge.

Another way in which the amount of time spent in learning can vary is in the assignment and the execution of homework. Frederick's study

showed that more students in the higher achieving schools were assigned (50% vs. 43%) and completed (90% vs. 65%) homework. In a sample of twenty high schools (McDill and Rigsby, 1973) the amount of time reported spent on homework varied between "none" and "more than 3 hours per day." Moreover, the more able students appeared to spend more time on homework than did the less able ones.

Absences, class disruptions, class interruptions, inattention, and limited homework are significant factors which singly, or in combination, alter how much time is spent learning. The extent to which these factors reduce the opportunities for learning is presently understood only to a limited degree. Detailed examinations of the amount of time engaged in learning compared to the amount of time supplied for learning are needed to clarify this important topic.

Exposure to schooling and learning

The important question remains--does more time in school make a difference for achievement? Research examining this question has produced a mixture of findings. Methodological and procedural defects and differences between studies may in part account for these inconsistencies. Few of the studies have been sensitive to the possibility that achievement gains and time spent may not be linearly related or that achievement gains and time spent may be related in a different manner for different individuals or groups of individuals.

The possibility that achievement and time are related in a non-linear fashion could help explain why some studies find positive effects for time spent whereas others find no effects for time spent on achievement. If, for example, achievement and time spent are related as depicted in figure 2.1, then the magnitude of the effect obtained for time spent

would depend upon the actual amount of time being considered. Figure 2.1 depicts, of course, but one type of non-linear relationship.

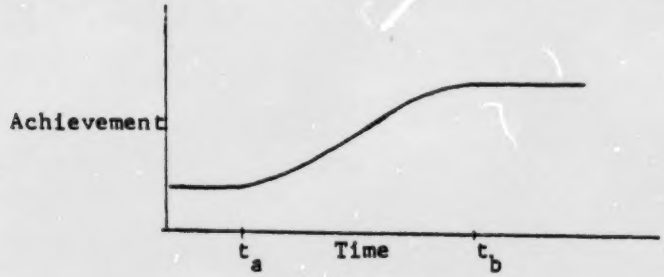


Figure 2.1
Achievement as Function of Time

If a student spent less than t_a amount of time then there would be no achievement effect. Or, if a student spent more than t_b there would be no achievement gain.

There is some limited support for the proposition that time and achievement are not linearly related. David (1974) surveyed 20 studies and found that extensive variation in exposure to schooling had a positive effect on achievement, but limited variation in exposure showed no consistent effects. Fisher (1976) in a careful examination of instructional time and student achievement, found that although these two variables were positively associated, "substantial amounts of time and substantial differences in amounts of time were necessary before this relationship could be detected" (p. 137). Himmelfarb (1977), in his study of the effect of length of exposure to Jewish schooling and religiosity, finds that there is a threshold below which exposure isn't particularly important and also a ceiling above which exposure isn't very important. Unfortunately, few studies have seriously attempted to use any other than

a linear relationship between time spent and achievement gained.

In addition, inconsistent results may have come about because different students are affected differently by the same exposure to schooling. Certainly, there is strong evidence that students need differing amounts of time to complete or master the same task (Bloom, 1976). From this observation, it follows that the same amount of exposure may have quite varied achievement effects. Most studies have not entertained the possibility that exposure to schooling and achievement effects will be different for different types of students.

This lack of consideration of the form of the exposure-achievement relationship and the neglect of consideration of individual differences no doubt contributes to the inconsistent nature of the findings. Additionally, the use of differing measures of exposure to schooling and differing measures of outcomes of schooling have confused the findings. Studies of exposure to schooling have used both elapsed time (e.g. days attending school) and engaged time (e.g. actual amount of time actively attending to a learning task). Because the same amount of elapsed time can connote quite different amounts of engaged time, results across these two types of exposure variables are frequently inconsistent. Also, differences arise even when active learning time is used, perhaps stemming from the use of an observer or the use of a teacher to record student behaviors.

Nor has there been consistent use of outcome measures in various studies examining the effects of school time. Grade point average, standardized achievement tests and criterion referenced tests are several of the outcomes which have been used.

In the following selected review of these studies, attention is given first to studies which have used elapsed time as the time variable and then to studies using engaged time.

Studies focusing on elapsed time

As a group, these studies have not examined the detailed usage of some duration of time, looking instead at the effect of such time variables as school absence, school term length and school day length on achievement.

Numerous studies have concluded that school absence and lower grades go together (Odell, 1923; Ziegler, 1928; Crider, 1929; Butler, 1925; Finch and Nemzek, 1940; Rozelle, 1968; Levanto, 1973). The direction of causality in this absence-poor grades relationship, however, is unclear. Students could achieve poor marks because they missed important work during their absence. Alternatively, because students achieve poor marks and find school less rewarding, they could choose to be absent fairly often. Most likely poor marks and absenteeism are mutually reinforcing.

Absences may be more detrimental for some students than for others. Douglas and Ross (1965) found that upper middle class British youth were not appreciably affected by prior absence, but the achievement scores of lower middle and working class children were. Absences may have differential effects too, depending upon their number and whether they occur over a consecutive number of days or one at a time. Ziegler (1928) and Levanto (1973) suggest that a long string of absences affects achievement more than the same number of absences singly spaced. Odell (1923) and Heyns(1976) suggest that absence is detrimental to achievement only if it is excessive.

School absence was incorporated by Wiley and Harnischfeger (1974) in their indicator of quantity of schooling. This measure equalled the triple product percent in attendance x number of hours per day x number of school days per year. Using the Detroit metropolitan schools from the Coleman Report data, they found that quantity of schooling for these schools varied between 750 and 1150 hours. In an analysis of the effects of quantity of schooling on achievement, impressive effects were documented. However, in a replication of their analysis using additional data sets, Karweit (1976) did not find comparable effects.

Inconsistencies also appear in analyzing the effects of the length of the school day and length of the school week. Harris (1968) found significant effects on achievement for the length of the school day, but studies using the IEA data (cross national comparisons) did not find strong consistent effects for the effect of the length of the school week on achievement in mathematics. Husen (1972) reports that in rural Norway school terms of longer length were not associated with correspondingly greater achievement.

Studies focusing on engaged time

Studies which have used elapsed time have been criticized because of the likely measurement error in the time variable. As Frederick (1977) and Berkeley (1978) point out, the same elapsed time can result in remarkably different amounts of instructional time. Several studies have focused on more proximate indicators of engaged time in order to understand the effects of time on learning. Most studies simply report correlations between amount of time spent on "on-task behaviors" and

achievement, with few apparent attempts at controlling for or determining the antecedents of "on-task behavior."

Olson (1931) found the correlation between time off-task (whispering) and honor point average of twenty-four high schoolers to be -.30. Morch (1956) determined that the correlation between amount of off-task behavior (looking around, slumping, whispering, etc.) and predicted test score behavior was -.58.

Several studies have examined the effect of time on-task on standardized achievement tests. Edminston and Rhoades (1959) found the zero order correlation between time on task and achievement of 94 high school seniors to be .58. Lahaderne (1968) observed four sixth grade classrooms over a three month period and found that time on task and reading achievement were correlated .52. Cobb (1972) found attentiveness to be the most significant in-class behavioral predictor of arithmetic, but not reading achievement, for fourth graders in two middle-class schools. Turnure and Samuels (1972) compared attention and reading achievement of first graders and found that percent of time on-task and reading achievement were correlated .44.

Kiesling (1977) obtained teacher reports of how instructional time was allocated to fourth, fifth and sixth grade New York students from five school districts. Amount of time (minutes) spent in whole group, small group and individualized instruction by teachers, reading specialists and teacher aides and a reading pre-test score were used to predict student reading achievement (both on standardized and criterion referenced test). Linear (X_1) and quadratic (X_1^2) terms were used for each time

factor and regressions were carried out separately by grade level. Both the linear and quadratic terms in the equations were often statistically significant. Moreover, the effects of time spent in a specific instructional mode seemed to depend upon the initial ability level of the student. Kiesling notes that high ability children "have the capacity for getting on whether or nor they receive large allotments of instruction" (p. 18). Kiesling's study is of special interest because it points out the complexity of the relationship between instructional time and outcomes and the likelihood that there are significant interactions among ability level, type of instructional mode and instructional time.

Looking over the wealth of studies on time and learning, only a portion of which have been briefly reviewed here, several possible methodological and procedural differences may account for the mixed findings. Studies have often failed to entertain the possibility that time and learning may not be linearly related. There are numerous, quite feasible ways, in which this non-linearity could occur. Students could need to attain a threshold value of time before learning occurred, corresponding to an insightful learning curve. Or, students could learn some material in a linear fashion at the beginning and then become bored with it and even start forgetting what they had learned (positive linear term and negative quadratic term). Obviously, studies which have only permitted linear effects can produce inconsistent or no findings if the functional form is not as assumed.

Second, studies have not been sensitive to the possibility that

different students may exhibit markedly different relationships between time and learning. There is evidence that these differences do exist (e.g. Kiesling's study); however, most studies have not specifically examined this possibility.

Third, the research has used a variety of measures of exposure to instruction obtained by numerous observational or other procedures. Some measures have been defined only at the level of the school or classroom; some have used elapsed time, others engaged time. Virtually no two studies operationalized time in school in a comparable manner.

At this juncture, it would be convenient to claim that the uncertainty of the effects of time on learning are simply due to the methodological difficulties mentioned above. Such a claim would imply that we were actually pretty clear about the mechanisms and means by which time affects learning and that the measurement problems were simply standing in our way. In other words, it would be tempting to conclude that our theoretical house was in order and that our lack of consensus was due to data problems. Whether this is the case or not is discussed in the next section which reviews several theories relating time and learning.

Footnotes for Section 2

1. Callahan (1962) discusses how the division of the school day into periods of a fixed length came into being in the context of the scientific management movement of the 1920's.
2. Baltimore City currently has a day time curfew coupled with several active "get the kids back into school" programs. No systematic evaluation of its effectiveness in combatting truancy has been completed, but during the first months attendance was up in the city schools.

3. Models and theories of learning incorporating time

Some of the major theories which incorporate time as a variable in learning are presented in this section. Two broad perspectives are discussed: an economic one in which time appears as a resource or as an input to the educational process and a psychological one in which time appears as a component of the teaching/learning process. While both perspectives seek to describe the determinants of the process of learning, the emphases and frequently the methodologies of the two perspectives are different. Without making too much of the differences between theories which are in general aimed at understanding similar phenomena, a discussion of these two orientations is now provided.

Economic Perspective.

Simply phrased, an economist would see the use of time in school as a resource which in combination with other resources or inputs determines the productivity of the school. The problem to be solved, or the interesting question to be asked in this framework, is how to allocate these resources to maximize the schools' productivity given budgetary and other constraints. Student time is seen as a resource, not because there is a purchase cost associated with it, but because it has an opportunity cost (Schultz, 1963). Opportunity costs consist not only of expenditures associated with pursuing an activity, but the value of what is foregone as well. The opportunity cost of schooling can be measured by what activities are given up in order to pursue education. One obvious activity that may be given up is holding a job; that is, one opportunity cost consists of foregone earnings. Other activities,

such as pursuit of alternative types of learning ("foregone learning")[1] or leisure time may be viewed as measures or education's opportunity cost.

Assessing opportunity costs of education has usually been confined to higher education. However, it has been suggested that even for secondary and elementary students, time in school is valued because it can be used for other purposes (Thomas, 1971). Child labor laws and compulsory schooling laws limit the sphere of alternative activities, but students can still pursue different learning or leisure time pursuits. Student time, because it can have alternate uses, is a valuable commodity which should be used efficiently. The goal of economic analyses then is to determine the appropriate mixture of educational resources, including student time, which will maximize the productivity of the school. Productivity is defined variously, but usually means the production of some cognitive level.

Knowledge about the effects of alternate ways to allocate time is important because time use, in contrast to other inputs, is a resource over which the principal and teacher have a great deal of discretionary control.[2] Moreover, there is often a greater degree of flexibility in alternative uses of time than there is in the alternative use of other resources. Thus, from a practical viewpoint of maximizing school efficiency in the production of learning, time factors occupy a special potential role.

Economic analyses of time and its effects on learning draw our attention to several fundamental issues--for example, what is it about the outcome of schools that we wish to maximize? It the educational

goal is the attainment of a minimum standard of skills for all students, schools might structure their day in an entirely different manner than if the goal is for every student to achieve the maximum possible skill level. If the goal is for students to learn a fixed amount over a certain time period, then still other organizations might be implemented. Before one can assess whether a method is productive, the production of what and under what circumstances has to be defined.

The economic analysis of time and learning focuses our attention directly on the issue of what it is about schooling that we wish to maximize and the relative importance of various resources for achieving this task. In part because of the methodology used to determine the importance of these resources, this perspective has not been overly concerned with the process of productivity. This emphasis on the process of teaching and learning has fallen more into the purview of psychologists concerned with learning theory. We are specifically interested now in learning theories which have incorporated time as a factor in producing learning.

Psychological Perspective

Carroll's (1963) model of learning is the foremost example of a theory having time as its central feature. Carroll expressed the degree of learning as the ratio or the time spent in learning to time needed for learning. Learning in Carroll's model is expressed as the degree of attainment or percent of material learned. Learning is with reference to an individual student and is not confined to a school setting; it is a general statement of the degree of learning which will occur.

Carroll further clarifies time needed and time spent by specifying the factors upon which they depend. Figure 3.1 represents Carroll's model.

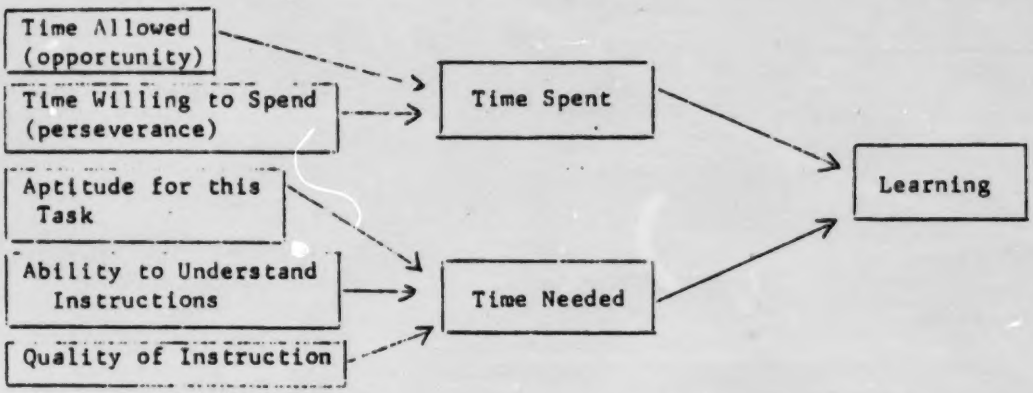


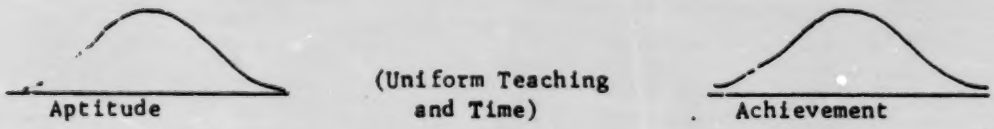
Figure 3.1

Carroll's Learning Model

Carroll's model grew out of his earlier work in foreign language attainment (Carroll, 1962) in which he had found that aptitude for foreign language determined both the level attained and the rate at which the level was reached. Thus the time needed to attain a certain level was in effect a measure of aptitude for the task. But, time needed was modified by the quality of the instruction and the ability to benefit from or understand the instruction. The time spent in learning was dependent upon the amount of time the child was willing to spend (perseverance) and the amount of time allocated to the task (the opportunity for learning).

Bloom (1976) translated Carroll's conceptualization of learning as a function of time into a strategy for "mastery learning."

Essentially, Bloom claims that because aptitudes predict the rate at which a student will learn a particular task, if enough time is supplied, most students can learn what it is that schools aim to teach. The strategy to assure learning is to fix the amount of material to be learned and let each student take as long as needed to master it. This approach is in distinct contrast to the traditional classroom in which the amount of time allocated to a specific subject is fixed and mastery of it varies. Bloom argues that in traditional teaching settings there is a high correlation between aptitude and achievement because students are supplied uniform instruction in terms of amount of time allocated. If the amount of time were made variable, then achievement would be less dependent upon aptitude. Block (1971), in describing these two learning situations, depicts the traditional one as follows:



and the mastery learning situation as

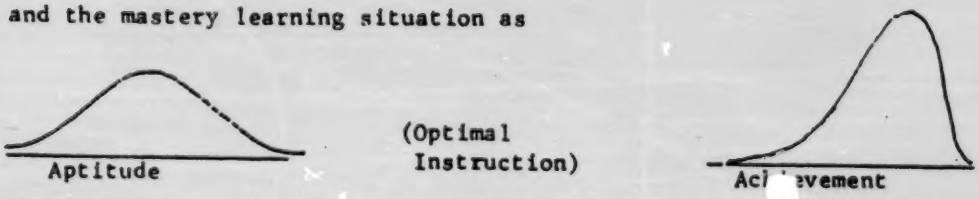


Figure 3.2

Traditional vs. Mastery Learning
Source: Block, 1971

In the traditional classroom setting, there is a fairly healthy correlation between achievement and aptitude because uniform teaching and fixed time constraints do nothing to lessen the dependence of achievement on aptitude. Under mastery learning, when everyone has enough time to complete the learning task, the achievement attained should look less like the initial aptitude curve.

Mastery learning has been implemented in traditional classrooms by dividing the course or subject into specific units of instruction, defining the required content for "mastery" of the unit, providing corrective and diagnostic feedback for individual students, and permitting students enough time to complete the unit to the prescribed mastery level.

Bloom has portrayed his model in Human Characteristics and School Learning in the following way:

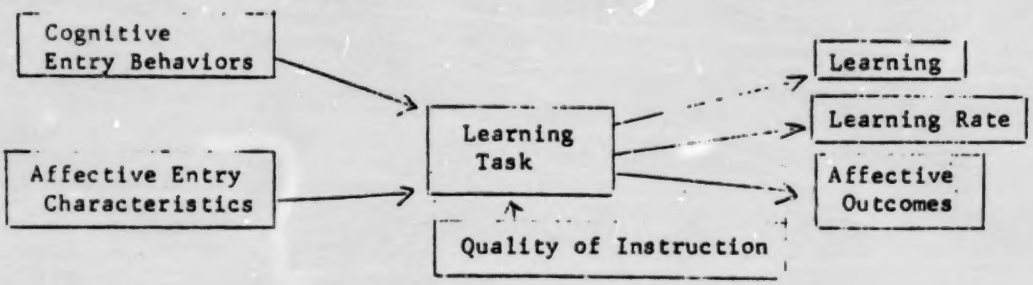


Figure 3.3
Bloom's Learning Model

A discussion of the model in detail is beyond the scope of this paper; but some of its important features will be elaborated. The guiding assumption of mastery learning is that most students can, if provided

enough time and high quality instruction, obtain mastery of specified skills. The empirically documented differences in the time taken to completion suggest that the slowest five percent of students will take approximately five times as long as the fastest five percent to complete the same material (Carroll, 1971). Rate of learning in traditional instruction then appears to vary markedly across individuals (and even for the same individual). A major claim of mastery learning is that these differences in rate of learning reflect differences in prior knowledge and that if students can be brought to the same level of mastery then the rate of learning on subsequent tasks will be similar. Differences in rate of learning then do not come about because of differences in the slope of the learning curve for brighter and duller students but in the length of the amount of time not spent in learning (see Zeaman and House, 1967, p. 205, figure 13).

One extremely important feature of mastery learning theory is its view of learning as dependent upon changeable, manipulable factors. Cognitive entry behaviors, affective entry behaviors and quality of instruction are not immutable factors. This conception of the determinants of learning clearly implies that how schools allocate their time can perpetuate, exacerbate or reduce the individual differences in achievement outcomes.

Threads from both Bloom's and Carroll's learning theories have been woven into Harnischfeger and Wiley's (1976) model of the teaching/learning process. The central feature of their model is that teacher activities and pupil pursuits are primary determiners of pupil achievement. These teacher activities and pupil pursuits mediate the influence

of school characteristics and teacher and student background characteristics on student achievement. In their model, whose rough dimensions are depicted below, the direct determiners of pupil achievement are pupil pursuits and pupil background.

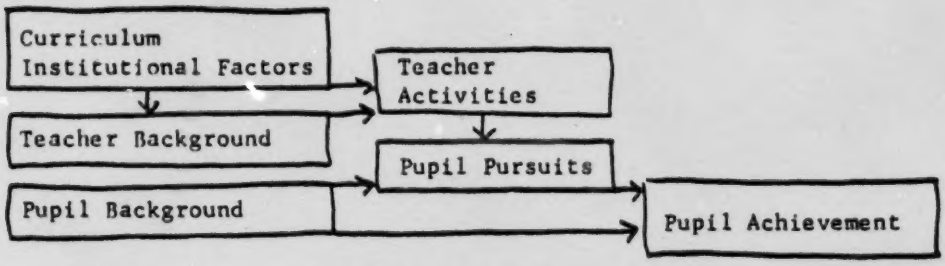


Figure 3.4

Harnischfeger-Wiley's Learning Model

A second issue which needs greater attention is how the nature of the learning task influences the amount of time required and the effects of spending certain amounts of time in learning. Certainly the difficulty of the task and the degree of structure of the task are two important elements which will determine how time spent will affect achievement gained. We would not expect that learning outcomes and time spent will be related identically for all tasks and students.

The Harnischfeger-Wiley model directly encompasses specific curriculum and institutional factors which have been of interest to researchers of the effectiveness of schools. Thus it serves to integrate somewhat the models of Bloom and Carroll with the input-output tradition of the school effects studies. That is, it attempts to embed the teaching/learning process in its educational/social context.

Other important issues

The above models all specifically incorporate time as a component of the learning process, either as an input to or mediator of the production of learning. However, as perspectives of the effects of time on learning, several critical issues are neglected. First, it appears to be assumed that the nature of the relationship between time and learning (although not explicitly spelled out) is linear. The assumption appears to be that more time in school (or on task) will produce correspondingly more learning and for all amounts of time spent or achievement attained. This may in fact not be the assumption of these models, but certainly the operationalization of these models in empirical studies does assume linearity (e.g. Wiley and Harnischfeger, 1974; Anderson, 1973). An adequate consideration of how time and learning in a school setting are related appears to be a fundamental but currently little understood topic.

A second theoretical issue which needs greater attention is whether (and under what conditions) time effects will be similar for different students. Clearly, our present intuitions about the meaning of a "brighter" vs. a "duller" student are rooted in our perception of how long it takes each to learn a certain amount. That is, intuitively we do not expect that learning outcomes and time spent will be related identically for all students, even given the same prerequisite knowledge (however, see Anderson, 1973 for a study suggesting that this intuition is misguided; also see Zeaman and House, 1967).

Third, these models focus our attention on only a few aspects of time utilization--the amount of time spent or the duration of a learning

activity, the learning rate, and the teaching rate. Although these aspects of time usage are clearly important, other candidates are important for determining how time as well as how much time should be allocated to schooling. For example, a student could spend the same amount of active learning time in virtually endless ways, some of which are likely to be more efficient than others. He could spend a forty-minute period in two fifteen-minute on-task sessions with one ten-minute break in-between, or he could organize the forty minutes into six five-minute on-task periods with two minute breaks in-between. From the standpoint of answering how instruction might be packaged to maximize achievement, knowledge of the relative efficiencies of alternate ways of organizing instructional time is required. That is, in addition to knowing how specific amounts of time affect achievement we need to learn how specific organizations of time affect achievement.

In the next section we develop a model of how teachers and learners, involved in a learning task, produce learning. In developing this framework, we will explicitly consider how variations in task structure, the packaging of instruction and efficiency of time spent affect achievement gained.

Notes for Section 3

1. According to Thomas, in The Productive School, this term originated with M. G. Bowman.

2. J. Alan Thomas makes this point in The Productive School.

4. A teacher/learner/task model

Introduction

This section presents a model of how teachers and learners produce learning. It is intended to capture the dynamics of the teaching/learning situation; it is not intended to be an exhaustive or definitive theoretical statement of how learning occurs. It does not define learning or teaching in precise terms but appeals to one's concept of what these terms mean. Nor does it elaborate how different characteristics of teachers and learners come about. Its intent is to provide a heuristic device with which the learning effects of alternative ways of arranging school time might be studied. The assumptions built into this model, which is operationalized as a computer simulation, are detailed now.

Learning is viewed as the result of a student and teacher paying attention to a learning task. The essential elements are the characteristics of teacher, learner and the learning task. The teacher provides information at some rate to the learner, who absorbs some fraction of this imparted information. Learning occurs if there is a change in the quality or quantity of knowledge held by the learner. Learning is broadly construed to mean acquiring new skills, behaviors, or concepts. A necessary condition for learning to occur is that both teacher and student are involved in the learning task.[1] If the teacher is presenting information and the student is daydreaming, he will not learn. Or, if the student is paying attention, but the teacher is interrupted, he will not learn. This model then views learning as the product of teacher and student effort on a learning task.

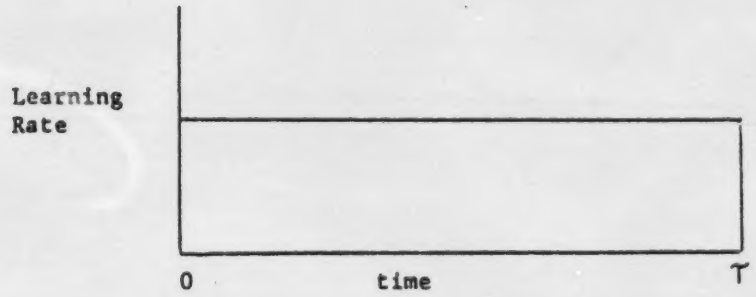
The model assumes that the same amount of time spent in learning may have different results for different students, and for different learning

tasks. The results of time spent depend upon the nature of the material to be learned (primarily its difficulty and its degree of cumulativeness) and how the teacher and student pace themselves through the material.

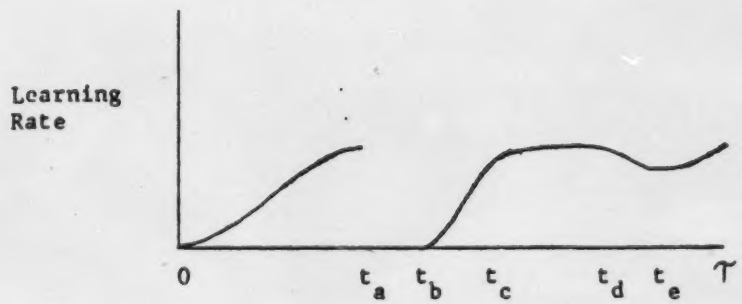
Another assumption of the model is that the same duration of learning time can be organized or packaged in numerous ways, some of which are more efficient for learning than others. The unit of time referenced may be hours, years, days or seconds--that is we may be referring to the temporal organization of the school day, the school year, the school week or some particular learning unit. Regardless of the unit of time, an important decision (although not typically recognized) is how active and non-active learning periods are to be arranged. The school year is based on a nine month "on" cycle and three month "off" cycle; however, other arrangements of "on" and "off" might be economically and educationally more efficient.[2] By recognizing that any duration of learning time is composed of "on" and "off" periods and by allowing the organization of these on and off periods to affect achievement, the model extends the usual question: " what is the effect of a certain amount of schooling" to "what is the effect of organizing a specific amount of schooling in alternate ways".

Our teaching/learning/task model (TLT) describes learning as the product of teacher and student effort on a learning task. The effectiveness of the teacher and student in producing learning is influenced not only by how much time is spent , but upon when and how it is spent. Thus, such a seemingly trivial episode as an interruption can have, in this model, an important learning effect depending upon when it occurs.

Fluctuations in student and teacher effectiveness are incorporated as well. Thus students can become bored or keenly interested in this model. Similarly, teachers can have good and bad instructional sessions. To illustrate the complexity of the learning situation which we hope to capture, Figure 4.1 depicts an idealized version of the learning rate throughout a span of time and what we claim is a more realistic version of learning rate throughout time.



idealized version of instructional time use



more realistic version of instructional time use

Figure 4.1
Instructional Time and Learning Rate

In the idealized version, the student has the same learning rate throughout the instructional sequence. We note that this assumption would generate a linear relationship between amount of time spent and learning achieved. In the more realistic version, the student has his ups and downs reflecting time it takes to warm up to a learning task (t_a), interruptions (from t_a to t_b), recovery from interruption (t_b to t_c), return to previous learning rate (t_c to t_d), onset of boredom (t_d to t_e), and recovery from boredom (t_e to end). These myriad fluctuations in the learning rate then are one feature of time use which need to be incorporated into a realistic model of the production of learning in schools.

Development of the TLT model

During any small interval of time, say from t to t + Δt, the teacher presents a certain amount of information, $\Delta V(t)$. The teaching rate can thus be defined as

$$K(t) = -\frac{\Delta V(t)}{\Delta t}$$

Or:

$$K(t) = \frac{dv(t)}{dt}$$

as $\Delta t \rightarrow 0$

The student has a certain efficiency in receiving and processing the information dispensed by the teacher. Assume that the teacher presents more information than he thinks the student will be able to grasp. The student's effectiveness in absorbing the given information is a ratio of what he absorbs, ΔI, to what the teacher has given, ΔV. Both ΔI and ΔV are functions of time, so we define student efficiency as

$$S(t) = \frac{\Delta I(t)}{\Delta V(t)} \Rightarrow \frac{dI}{dV}$$

Similarly, we can define a learning rate $R(t) = \frac{\Delta I}{\Delta t} \Rightarrow \frac{dI}{dt}$

What we are interested in is the amount of learning at some time L(t), which we write:

$$L(t) = L(0) + \int_0^t R\,(t')dt'$$

This says that the total amount of learning at time t for an individual student, is equal to his initial amount of knowledge, L(0), plus what he learned in the span of time t. In a simple example, assume that the student is learning for twenty minutes and that he learns at a constant rate of 5 units per minute, or R = 5 for all t. At the end of 20 minutes he will know 100 units since

$$\int_0^{20} 5dt = 5t\Big]_0^{20} = 5 \times 20 - 5X0 = 100$$

This corresponds to a uniform learning situation.

Previously we stated that learning comes about as the product of teacher and student efforts on a learning task. Because both student and teacher have to be involved, we express the rate of learning as the product of a teaching rate K(t) and a student efficiency S(t) or

$$R(t) = K(t)\ S(t)$$

where S(t) is the fraction of what the teacher taught that the student learned. Now, because we are interested in how teacher/learner efforts produce learning, we really want to consider:

$$L(t) = L(0) + \int_0^t K(t')S(t')dt'$$

In the trivial case, K and S may be constants so that L can be expressed algebraically as:

$$L(t) = L(0) + KSt$$

This corresponds to the situation where the teacher and student teach and learn uniformly. This is the case considered in static learning models, which becomes simply a particular case in this dynamic model.

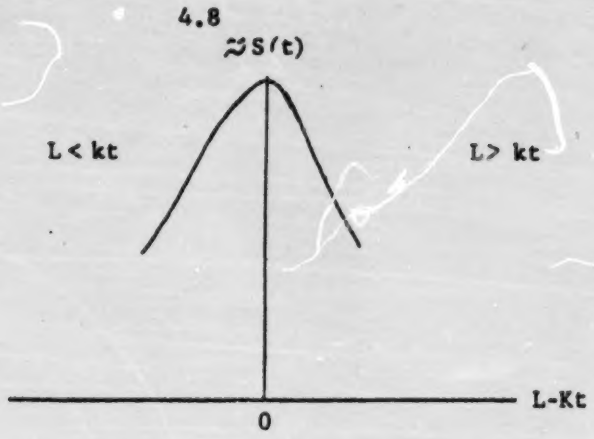
We now consider two factors which affect the amount of information which the student will gain during a specific interval of time. First, the nature of the learning task, in particular the degree of cumulativeness of the material, is proposed as an important element determining student efficiency. Second, the level of knowledge that the learner has and its difference from what the teacher expects him to have is proposed as a factor affecting efficiency. These factors, along with the student's aptitude for this learning task and interest in the learning task determine the student's efficiency in learning.

First, imagine that the student is learning a cumulative subject in which there are prescribed prerequisites for each learning task. An obvious example of such a subject might be a mathematics course, in which acquiring new skills is highly dependent on thoroughly learning old ones. Also, assume that the teacher teaches at a fixed rate; that is, he imparts the same amount of information per each unit of time in the teaching period. Although this assumption of a constant teaching rate is clearly unrealistic over a whole sequence of teaching, it is a useful temporary simplification.

Now, the teacher expects that the student will know a certain amount of the material which has been presented. In general, we assume that teachers do not expect their students to learn everything they present. Imagine that the teacher expects the student to have learned V=Kt amount in the time t during which the teacher teaches at the rate K.

In one learning session, we assume that the teacher will present more material than he expects the students to grasp. In the next learning session he repeats some fraction of the previous lesson. If the student knows more than the teacher expects, that is, he got the material the first time around, he isn't really learning anything new when the teacher repeats it.[3] So, his efficiency is reduced because he knows more than the teacher expects. The student who knows less than what is expected also has his efficiency reduced because he is trying both to understand what he needed to know (the prerequisites) plus the new information being given out. Only when the student knows about what the teacher expects him to know can his efficiency in learning be at a maximum. We term this part of total student efficiency which reflects the difference between teacher expectations and student knowledge the student's <u>relative efficiency</u>.

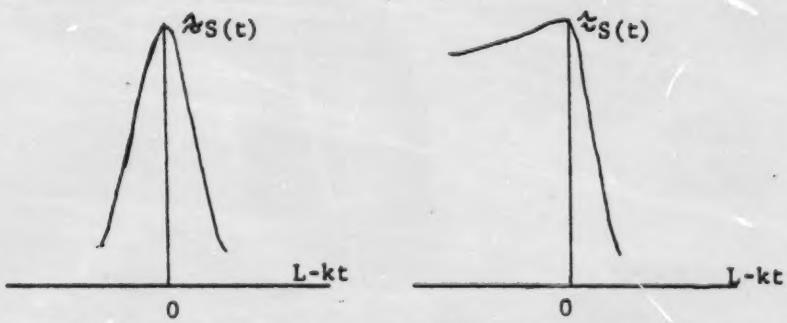
Figure 4.2 shows one way in which relative efficiency and teaching-learning discrepancy might be related. The x axis is the difference L-Kt. The y axis represents his relative efficiency. The maximum relative efficiency occurs when L=Kt; as we have depicted the relationship here when L $<$ Kt or L $>$ Kt the gain in information is similarly diminished.



Relative efficiency as a function of the difference between student knowledge and teacher knowledge expectation

Figure 4.2

For a very cumulative learning task, the efficiency should be drastically reduced when the student does not know what is expected of him. This is so because each step requires a high degree of master before the next step can be understood. For a less cumulative task, the efficiency should not be so drastically affected. Figure 4.3 depicts relative efficiency as a function of teacher-learner discrepancy under these two types of learning task structure.[4]



Cumulative Learning Task

Less Cumulative Learning Task

Figure 4.3

Relative Efficiency , Curriculum Structure and Teacher-Learner Discrepancy

For a cumulative learning task, the student's relative efficiency drops markedly when he is not where the teacher expects him to be (left panel). For less structured learning tasks, the difference L-Kt is not as critical, especially for the efficiency of students who know less than what the teacher expects (L-Kt< 0).

In order to operationalize these notions regarding the effect of curriculum structure and teacher-learner discrepancy we need to give a functional form to the relationships described by Figures 4.2 and 4.3. We require that the function have its maximum value in the "middle" and that it decrease on either side of this maximum. In addition, the decrease may not be the same on one side of the maximum as it is on the other (e.g. right hand panel of Figure 4.3). Although there are numerous functions which might describe this relationship, we arbitrarily select two separate halves of a normal curve; i.e. if L-Kt<0 then efficiency can be described:

$$S = ce^{-\left[\frac{L-Kt}{\Sigma_-}\right]^2}$$

If L-Kt>0, the efficiency can be described:

$$S = ce^{-\left[\frac{L-Kt}{\Sigma_+}\right]^2}$$

where c and Σ are, for the moment, unspecified factors. Our equation for student efficiency then becomes

$$S = ce^{-\left[\frac{L-Kt}{\Sigma_t}\right]^2}$$

Because we have learning tasks which take different amounts of teacher time to present, it is useful to consider this function for S(t)

in terms of the total teaching task time. That is, it is useful to be able to speak in terms of percent of the task completed, expressed as $Kt/K\tau$ where τ is the total task time. $Kt/K\tau$ then indicates how far along the teaching/learning task is in terms of its total needed time. We can implement this by rewriting Σ_+ as $\sigma K\tau$ so we now have:

$$S = ce^{-\left[\frac{L-Kt}{\sigma K\tau}\right]^2}$$

where $L-Kt/K\tau$ is the fractional difference between teacher expectation and student level and σ_+ measures the width of the curve.

We have defined the student's efficiency in learning to be the amount of information absorbed in comparison to the amount given out. The preceding discussion has pointed out how the relative efficiency of the student depends, in part, upon his previous knowledge, the teacher's expectation and their difference and upon the degree of inter-relatedness or cumulativeness of the learning task. In addition, the student's efficiency will depend upon the rate at which the student is willing or able to absorb the new information. That is, in this model we will specifically allow for the condition that students with the same amount of knowledge may have different abilities for or interests in a subject which, along with their previous knowledge and nature of the learning task, determines their change in information. In the model, this condition is operationalized by the term c.[5]

Our formula for S describes this component of student efficiency as the product of his "match" with the teacher's rate of instructing and his "match" with the teacher's assumed level of information. Using this

expression for S, the equation for learning becomes:

$$L(t) = L(0) + \int_0^t K(t')c(t')e^{-\left[\frac{L-Kt}{\sigma K\sqrt{\tau}}\right]^2 \frac{1}{2}} dt'$$

Experiments Using the TLT Model

The equation above describes the accumulation of learning for a single student during some length of time (from 0 to t) as a function of his initial knowledge, the teaching rate, the cumulativeness of the curriculum, his aptitude for the task, and the discrepancy between his knowledge and his teacher's expectations. We will use this formulation, operationalized by a computer simulation, to examine what consequences some assumptions about our teachers and learners and the learning task will have on the production of learning. These examinations are accomplished by carrying out "experiments" using the computer program to generate the results. Given the number of factors that the model is seen to depend upon, the "experimentation" provided here should be seen simply as examples of the potential of the model for addressing interesting issues. In this presentation we focus on only two aspects of time use: 1) the effect of the discrepancy between teacher expectation and student learning and 2) the effect of interruptions on learning. These two topics, although somewhat limited in scope, do illustrate the utility of the model for incorporating non-linear effects, task structure effects and packaging effects.

Teacher Expectation and Student Level of Knowledge

Faced with the task of lecturing to thirty students, a teacher makes some assumptions about the level of knowledge of the students and gears the instruction to that level. In this section we use the TLT model to

illustrate the consequences for learning for students who a) know less than the teacher expects and b) know more than is expected. These particular experiments are somewhat unrealistic in that we assume the teacher teaches at a constant rate. That is, regardless of evidence that the class is getting bored or lost, we depict the teacher as going at the same rate. However, despite these simplistic notions, we will see that some interesting, and familiar, student outcomes result.

The Effects of Knowing Less Than the Teacher Expects

Assume that the teacher expects the student to learn one unit of information per unit time. In practice the teacher presents more than one unit, but the expectation is that the student will learn at this rate. Also imagine that we have a student who is not able to perform to the teacher's expectations in the given time, assume he gets 90 percent of what the teacher expects. In a highly structured curriculum (i.e., small value for σ implying a pinched-in information-discrepancy curve--refer to Figure 4.2 left hand side), the effect of knowing less than is expected accumulates over the learning sessions. The student knows progressively a smaller and smaller fraction of what the teacher expects. At some point, the student becomes so far away from where the teacher expects him to be that he stops accumulating information. Figure 4.4 was obtained from the simulation by setting K=1.0, C=.9, σ =.05, L_o=0 and t=50. In the simulation random fluctuations around the student's C value are permitted. These fluctuations are used to simulate periods where the student is momentarily bored or extremely interested in what is being taught, i.e., they reflect variations in the intensity of his attentiveness. Looking at Figure 4.4, we see that this student stays below the teacher expectation

and at point t_q simply stops gaining in achievement. At this point, the student is so far behind what the teacher expects that his efficiency becomes essentially zero and he stops accruing information.

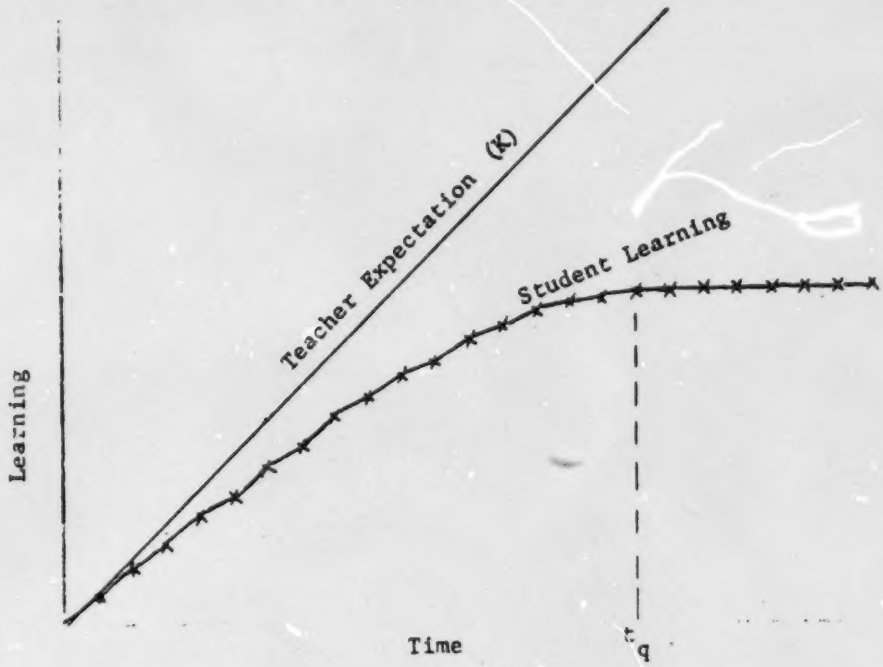


Figure 4.4

Cumulative Effect of Knowing Less
than Teacher's Expectations

The Effects of Knowing More Than the Teacher Expects

We also generated a cumulative learning curve for students who learn more than their teachers expect. Recall that in our model teachers do not expect the student to learn everything they teach; the K plotted here is for what they expect the student to actually learn. The teacher actually teaches more than the K value per unit time.

In Figure 4.5, the cumulative learning curve is displayed for C=1.4 and a teacher expected learning rate of 1.0. The student's progress is characterized by "bursts" of learning in which he keeps up with the actual teacher rate (which is more than the teacher expects him to do),

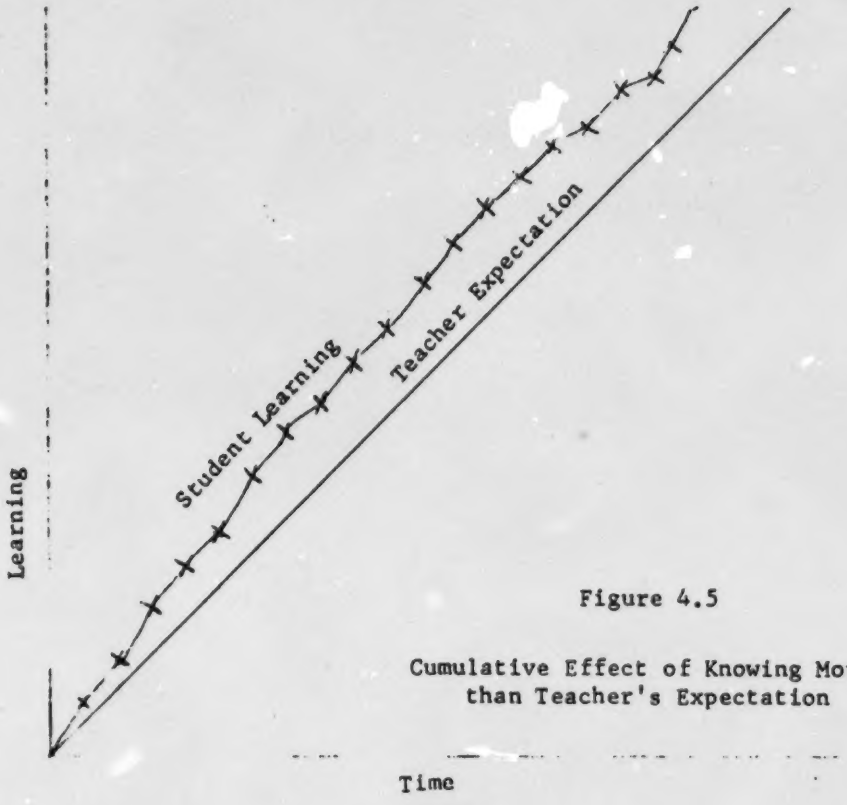


Figure 4.5

Cumulative Effect of Knowing More
than Teacher's Expectation

followed by a period of coasting in which the student is waiting for the teacher to teach him new materials. Imagine the learning situation in which the teacher presents in one day all of that day's lesson plus a preview of the next day's lesson. The more able student may get all of the information taught the first time around (the first day) so that on the second day he is coasting waiting for the teacher to present new materials. The more able student then has an erratic learning rate (bursts followed by "coasts") because we assume that he does depend upon the teacher for learning and that he can learn faster than the teacher expects.

The above presentation describes the cumulative effect of knowing less than or more than the teacher expects. A comparison of the results displayed in Figures 4.4 and 4.5 points out how the TLT model incorporates differences between slow and fast learners in their accumulation of learning. A slow learner is allowed to fall

arbitrarily far behind. A fast learner, however, is not allowed to get arbitrarily ahead of the teacher. This feature of the TLT model is important to understand for it has a significant impact on how various teaching strategies affect learning outcomes. In the next section we discuss the cumulative effects of various teaching strategies (rates) for a hypothetical classroom.

Cumulative Effects of Teacher-Student Discrepancy for a Class

The average ability level of our class of 30 children was .94. The distribution of abilities was obtained by generating 30 random normal deviates and transforming these to a distribution of mean 1.0 and standard deviation .2. These 30 students represent our classroom of learners on which we conduct our teaching experiments. The experiments consist of varying the teaching rate and varying the structure of the curriculum. We set the teaching rate to range from .70 to 1.10 in .05 increments and for each teaching rate let the degree of structuredness of the curriculum (σ) take on values of .05, .10, and .15. Referring to equation 1, the upper limit for t was 50 and dt was .01. In Table 4.1, we provide the average amount of learning per class in each of these teaching situations. Referring to Table 4.1, we find that a teaching rate of .70 with the most structured curriculum (σ = .05) produces an average achievement of 3.31. For this simulation run, the teacher's expectation of cumulative knowledge would be .70 x 50 x .01 = 3.5. Inspection of this table reveals that maximum average achievement occurs when the teacher teaches at a rate below the average ability level of the classroom.

Table 4.1 Here

In this case the maximum achievement was at .75 or .80 for an ability level of .94. Given the way we have structured the learning situation the

Table 4.1

Achievement as a Function of Teaching Rate
with Hierarchical Curriculum

Teaching Rate	Average Achievement		
	σ = .05*	σ = .10	σ = .15
.70	3.31	3.48	3.61
.75	3.39 '	3.68	3.78
.80	3.38	3.60	3.86
.85	3.29	3.40	3.75
.90	3.26	3.42	3.72
.95	2.90	3.33	3.67
1.00	2.34	3.08	3.48
1.05	2.25	2.80	3.27
1.10	1.53	2.65	3.11

* These represent values which were utilized in evaluating

$$S(t) = ce^{-\left[\frac{L - Kt}{\sigma\sqrt{Kt}}\right]^2}$$

' Maximum achievement values are underlined.

learning efficiency is reduced equally when the student knows more than teacher expects and when the student knows less than the teacher expects. That is so because we have assumed a symmetrical curve as in Figure 4.1 and have assumed a very structured or hierarchical set of materials in which falling behind in one session is highly detrimental for the learning in the next section. We have structured a learning situation in which it is easy to fall behind and difficult for the student to catch up once he has fallen behind. Consequently, the maximal learning for the class is produced if the teacher teaches a little below the average so that the less able students are able to keep up.

Now, such a situation may characterize a highly structured set of curricular materials where it is imperative that a thorough understanding of one concept be gained before proceeding to the next. In several other learning situations we can imagine that such "fine tuning" is not necessary. In less hierarchical tasks, such as acquisition of historical facts, achievement at one step may not be as dependent upon achievement at a previous step, so knowing less than what was expected would not so greatly affect the learning rate. The learning rate is not symmetrical around the expected student value in this case.

Again, applying our computer simulation of our hypothetical teacher and students, we examined the effect on learning of this type of curricular material being taught at seven different teaching rates (the columns) and for different types of learning tasks (the rows). The values for σ indicate the relative degree of structure of the curriculum, a larger value representing a less inter-related set of learning tasks. This table was generated using six different types of learning tasks. These cover a range of values for σ_- (the effect of knowing less than the teacher expects) and the same value for σ_+ (the effect of knowing more than the teacher expects).

Insert Table 4.2 Here

From Table 4.2 it is apparent that maximum achievement is not produced by the same teaching strategy for all types of learning tasks. When the curriculum is not very hierarchical (e.g., $\sigma_{-} = .70$), the maximum learning occurs when the teacher presents material appreciably faster than what the students can, on average, learn. In this teaching setting, the cumulative impact of not knowing what the teacher expects is not compounded in the same way it is in a highly inter-related learning task. In addition, at the faster teaching rate, the more able students are allowed to proceed at a more appropriate rate. On the other hand, if the curriculum is fairly structured (e.g., $\sigma_{-} = .20$) then the maximum achievement results when the teacher teaches somewhat below the average level of the class. This teaching rate assures that the less able students will not be lost.

The Distribution of Ability and Achievement

In Table 4.2 we presented the average classroom achievement for different teaching rates and for curricula with varying degrees of hierarchy. We saw that in a very structured curricula where learning at one time was highly dependent upon the cumulative knowledge base, the maximum amount of learning was produced when the teacher taught somewhat below the average classroom ability level. This result comes about because the slower students then are more able to keep up with this pace. However, for less structured curricula, a different teaching strategy was found to produce maximum average achievement. In this case, average achievement was maximized when the teacher taught at a faster rate.

Maximal average classroom achievement is one type of educational goal and we have suggested how it might be produced under differing conditions

Table 4.2

Achievement as a Function of Teaching Rate
with Less Hierarchical Curriculum

Teaching Rate	Average Achievement $\sigma_- \sigma_+$* .20/.05	$\sigma_- \sigma_+$ .30/.05	$\sigma_- \sigma_+$ .40/.05	$\sigma_- \sigma_+$ .50/.05	$\sigma_- \sigma_+$ .60/.05	$\sigma_- \sigma_+$ .70/.05
.80	3.75	3.87	3.90	3.91	3.92	3.94
.85	3.82	3.96	4.03	4.08	4.09	4.09
.90	3.78	4.03	4.14	4.20	4.20	4.23
.95	3.79	4.07	4.21	4.27	4.32	4.35
1.00	3.74	4.06	4.26	4.31	4.41	4.43
1.05	3.46	4.03	4.28	4.38	4.44	4.48
1.10	3.34	3.89	4.24	4.35	4.44	4.52

*These represent values which were utilized in evaluating

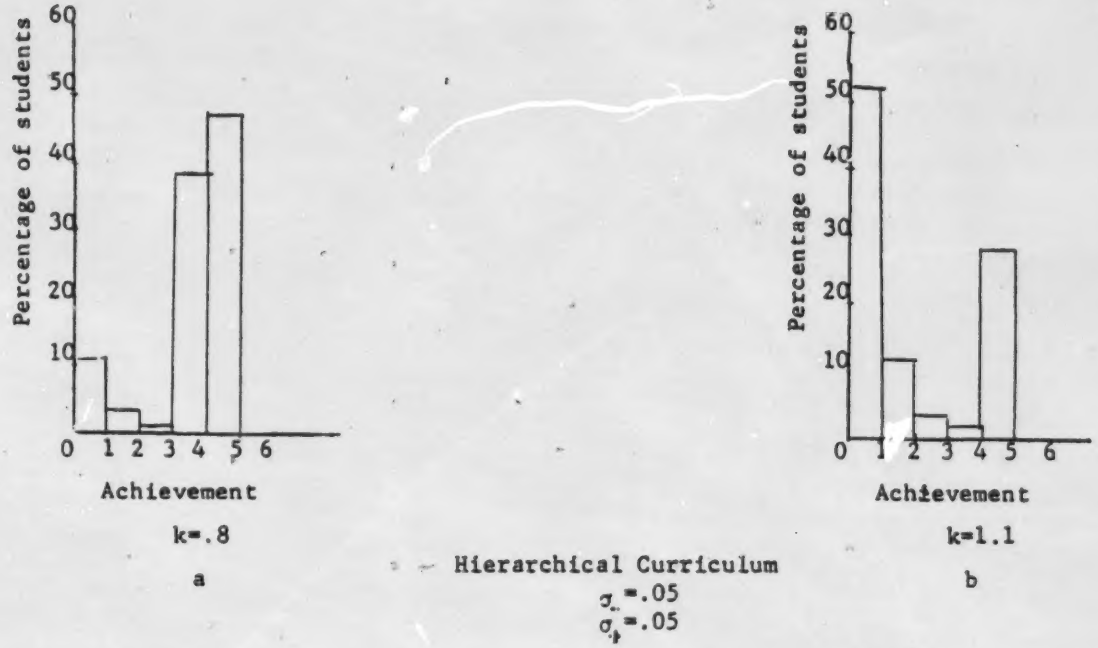
$$S(t) = ce^{-\left[\frac{L - Kt}{\sigma_{\pm} K\tau}\right]^2}$$

where σ_- was used if $L-Kt < 0$
σ_+ was used if $L-Kt \geq 0$
τ time to completion

of teaching and curriculum. Other educational goals strive not to maximize some average value but to alter the distribution of achievement around some value. The present interest in having all children attain a certain minimum competency in the basic skills is one example of an educational goal specifically aimed at the distribution of achievement. Assessing the optimum way to achieve such a goal then involves an examination of achievement distributions under differing learning and teaching conditions of different curricula.

The TLT model may be useful for this endeavor as we can vary the conditions of teaching, learning and task and study the effects on the distribution of achievement scores. Because we are interested in distributional properties and wish the results to be stable, we ran the simulation using 1000 students as the base, having a mean of 1.0 and a standard deviation of .2. We first assume that the learning task is very structured ($\sigma_- = .05$, $\sigma_+ = .05$) with a teacher who teaches slowly (panel a in Figure 4.6) and with a teacher who teaches more rapidly (panel b). Next, we suppose that a less structured set ($\sigma_- = .70$, $\sigma_+ = .05$) of materials is being presented at a slow pace (panel c) and a fast pace (panel d). The figures a, b, c, d show the percentage of students who have a certain range of achievement values under each of these teaching/curriculum combinations.

Figure 4.6 About Here



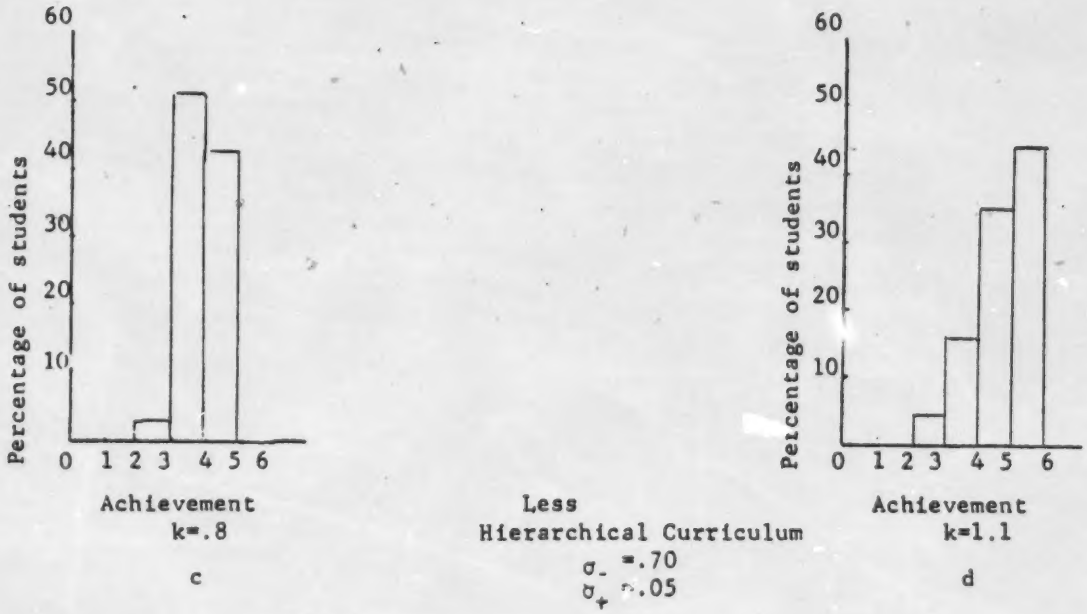


Figure 4.6
Distribution of Learning by Teaching Rate and Task Structure

For a very structured curriculum, we saw earlier that the maximum average achievement occurred when the teacher taught at a relatively slow pace. But teaching at this pace produces a highly concentrated achievement curve in which about 80 percent of the cases are clustered at or a little above the mean. The average in this case was 3.6 and no one achieved more than 4.2. If the teaching goes relatively fast as shown in panel b, then the classroom average is reduced to 2.3 but the spread around that average is greatly increased. In this example, 50 percent of the students had an achievement less than 1 but 33 percent had achievement greater than 5.0. Most of the class would be penalized by the teaching at this rate, except for the more able students who do very well. These differing achievement distributions have been obtained for the same students by varying the pace of teaching.

In panels c and d we examine what happens in a less hierarchical curriculum with slow and fast teaching paces, again with our same classroom of students. When the teacher goes slowly there is still a clustering of students a little above the average value. The average achievement value in panel c is higher than panel a, reflecting the ability of the slower students to do better. The faster students are of course penalized at this slow teaching rate for either kind of curricula. If the teacher teaches faster, the distribution of achievement appears similar to what we have sketched in panel d. There is a long slow incline and then a clustering of students at 5.5 and 5.6. Had the teacher taught at a faster rate this clustering at the higher values would have spread out, but probably would have been accompanied by a reclustering at the lower end indicating the slower students were completely left out by this teaching pace.

What is interesting about these examples is the widely differing distributions obtained under the differing teaching/task conditions to which we have subjected our hypothetical classroom of learners. These differing distributions suggest how teachers might use their allocated instructional time to achieve specific educational goals. If the goal is to maximize achievement, we have already suggested how this might be accomplished--teach faster for less structured materials, more slowly for more structured materials. If the goal is to have all students pass a minimum standard of competency, then the best strategy is to present the material at a slow pace. This goal can be met by such teaching, but with a penalty for the more able students who are idling most of the time. In this situation, the achievement scores are clustered around one or two values.

The Effects of Interruptions

Interruptions may have a dramatic impact on learning because the learning rate becomes zero while the interruption is in effect and because it takes time to return learning to its former or near its former rate. Both the length of the interruption and the length of the recovery time are important in determining the impact of interruptions on learning. We don't really know how long it takes to recover from interruptions or actually very much about how often they occur in a typical classroom.[6] To study their effects using our TLT model, we constructed a learning sequence in which there were 4 periods of zero learning, followed by 4 periods of learning at half the normal rate.[7] Figure 4.7 illustrates the way we operationalized the interruptions and Table 4.3 provides the effects on achievement of these interruptions for differing curricula and rates of teaching.

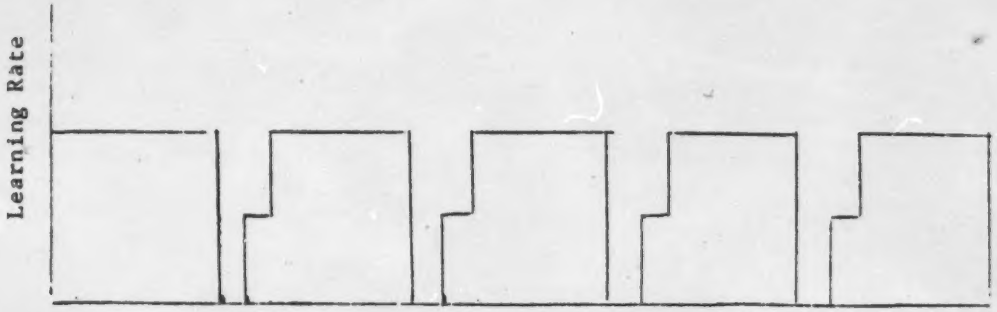


Figure 4.7

Interruptions and Recovery
(as operationalized)

Table 4.3 Here

From inspection of table 4.3 we see that learning is diminished appreciably by the time taken for interruptions and recovery from them. Especially interesting is the impact which interruptions appear to have on determining the optimum teaching rates for the various curricula. Comparing the interrupted sequence (Table 4.3) with non-interrupted sequence (Table 4.2), the interrupted sequence systematically produces its maximum learning at a lower teaching rate (e.g. for σ = .70, the maximum learning occurs at 1.10 in the sequence without interruptions, for σ = .70 the maximum learning occurs at .95 for the sequence with interruptions).

In the example here we arbitrarily chose an interruption of a certain length and a certain recovery rate. We would expect that differing lengths and recovery times would have differing impacts on learning. We have also returned the student to his former learning rate after each interruption. One can imagine that the student might be able to tolerate a few brief interruptions without having his return efficiency affected greatly.

Table 4.3

The Effect of Interruptions on Achievement
for Fixed Teaching Rates with
Less Hierarchical Curriculum

Teaching Rate	Average Achievement				
	$\sigma_- \ \sigma_+$ .20 /.05	$\sigma_- \ \sigma_+$ .30/.05	$\sigma_- \ \sigma_+$ .40/.05	$\sigma_- \ \sigma_+$ .50/.05	$\sigma_- \ \sigma_+$ .70/.05
.80	3.13	3.34	3.45	3.50	3.56
.85	3.05	3.30	3.48	3.57	3.63
.90	2.97	3.30	3.46	3.58	3.66
.95	2.75	3.24	3.45	3.57	3.70
1.00	2.48	3.07	3.39	3.55	3.69
1.05	2.32	2.90	3.30	3.45	3.67
1.10	2.06	2.83	3.23	3.43	3.65

*These represent values which were utilized in evaluating

$$S(t) = ce^{-\left[\frac{L - Kt}{\sigma_{\pm} KT}\right]^2}$$

where σ_- was used if $L-Kt < 0$

σ_+ was used if $L-Kt > 0$

However, after a series of such episodes, tolerance for them is no doubt diminished and the student probably has his learning rate drastically reduced by a single episode (the straw that broke the camel's back). Consideration then of the timing, the frequency, and the length of the interruption is necessary in order to assess its effect on learning rate.

Boredom, fatigue, recovery from boredom and fatigue, "start-up" periods and "wind down" periods are all episodes in learning which are qualitatively similar to interruptions, and which we could incorporate into the model. Again the important features of these elements are the length of their effect and where appropriate their recovery time.

Using the TLT model, learning has been shown to be drastically affected by the mismatching of teacher and learner, by interruptions and by type of curriculum. It is most useful to note that these apparently disparate phenomena can all be characterized by a common feature--the time needed for completion of the event, or time scale. We suggest that knowledge of the relative magnitude of these time scales is necessary information for rationally selecting from alternate educational uses of allocated time. The relative magnitude of the time scales of these learning events should provide insights into why some uses of time are more productive for learning than others. We thus suggest that to maximize the productivity of learning over a given span of time, attention needs to be paid to the time scales of learning events, the topic of section 5.

Notes for Section 4

1. Although the present formulation of the model is geared primarily to the traditional lecture mode of teaching (which comprises the greatest proportion of the school day) it can easily be made to accommodate other modes of instruction (seatwork, small group instruction, individualized instruction).
2. Year round schools, of course, are examples of alternative arrangements of on and off times.
3. Of course, repetition may in actuality provide a method by which overlearning occurs, this model does not distinguish between learning and overlearning of the material.
4. No precise formulation of "structured" or "cumulative" learning task is supplied here. The fundamental variable which we are after here is the degree of relatedness or interdependency of the various components of the learning task.
5. We substitute the word ability for the c factor in this discussion, without defining precisely what is meant. It could reflect motivation, interest, specific aptitude, general aptitude. It operationally means the property of benefitting from this mode of instruction.
6. Jackson (1968) observes that petty interruptions characterize the elementary school classroom and that "students are expected to ignore these distractions or at least to turn quickly back to their studies after their attention has been momentarily drawn elsewhere" (p. 16).
7. We do not mean to imply that interruptions operate as a step-like function; this function was simply a convenient one to incorporate and one which roughly mirrors the effect of interest.

5. Time Scales and Time Allocation Choices

Time Scales and Learning Events

We have proposed that any period of instructional time can be used in numerous ways, some of which are more productive for learning than others. This section discusses how knowledge of the time scales of learning events is fundamental to the issue of the productive use of time. We begin by describing what is meant by a learning event and by a time scale. Next some examples are provided which illustrate how knowledge of time scales could be used to select educationally productive uses of allocated instructional time.

We have assumed that a student does not have a uniform learning rate but instead may exhibit considerable variation reflecting interest or boredom in the subject or mode of presentation, appropriateness of the instruction and other situational factors such as interruptions or distractions. One of the features of the TLT model is its incorporation of these fluctuations in the learning rate. There are factors which increase the learning rate and factors which have a negative impact on learning rate. Collectively we have termed these factors learning events. Keen interest in a topic and knowing about what the teacher expects you to know should increase the learning rate. On the other hand, if the student is not where the teacher thinks he is (either knowing less than or more than the teacher's expectations) or if the student is bored, then the learning rate should be diminished. In order to examine how these factors will affect the learning rate we need to know their time scale, or time over which they are in effect. For example, we need to know how long a student can maintain a keen level of interest before fatigue or boredom sets in.

These learning events can all be characterized by how long they take to complete, or by their time scales (also phrased their characteristic times). Some learning events are never completed, but these can be characterized by the time it takes to be nearly or say half or 99 percent completed.

We are interested in time scales in learning so that we can decide what combination of components of learning will maximally produce achievement. In the preceding pages we have suggested a model that consists of factors involving learning each of which has an inherent, albeit unknown, time scale. We can list these times:

τ time to completion of teaching

τ_D time to degradation of learning efficiency

τ_B time to boredom

τ_R time to recover from boredom

τ_U average time of interruption

τ_M mean time between interruptions

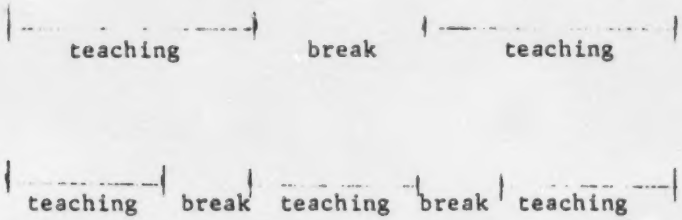
τ_S time to recover from interruption

What we now emphasize is that the relative magnitudes of the various time scales should determine how we go about selecting educational strategies, and that decisions about packaging instruction in alternate ways should entail utilizing information about the time scales of these learning events.

Examples of Decision-Making Using Time Scales

For example, if a teacher wishes to attain a specific educational objective, knowledge about the characteristic times of these learning

events for his particular learning task is required. Would it be better (i.e. more productive) to have one long time period of instruction with one break or two shorter periods with two shorter breaks interspersed? These two situations are depicted in Figure 5.1 below:



Alternate Ways of Organizing Instruction and Breaks
Figure 5.1

The important consideration that the teacher has to keep in mind in deciding whether to use two smaller breaks or one larger break (same total length) is the amount of time it takes to recover from a break in comparison to the amount of time it takes for the students to become bored. If the time to boredom (see Figure 5.2 left side) (τ_B) is significantly longer than the recovery time from the break (τ_R) then the best strategy would be to have very frequent breaks.

If the time to recovery (τ_R) is greater than time to boredom (right side Figure 5.2) then it would be better to have few or no breaks in the instructional period.

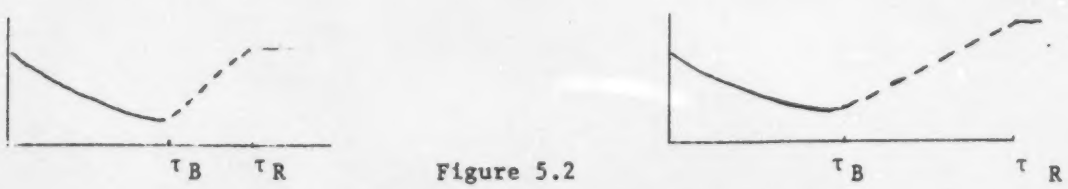


Figure 5.2
Time to boredom, time to recovery

We consider knowledge of these characteristic times of learning events to be crucial for making reasonable selections among alternate ways of alloting instructional time. The example just used pertained to a single teacher's choice in packaging instruction over a single instructional sequence. The importance of knowledge about characteristic times is not limited to such a micro facet of the allocation issue, however. As another example, we consider alternative ways of packaging instructional days over the school year. Given that schools could run for only half their normal session some possibilities are:

1) Run school every school day for 90 normal school days (e.g. half the year).
2) Run school every other day for 90 days, spread out over the normal school year.
3) Run school every day for one-half the usual school day length.
4) Run school 4 consecutive school days, off the fifth, of normal school length for a school term of 144 days.

Suppose (quite unrealistically) that the only thing which had to be considered was the maximization of some learning objective. That is, we assume all options cost the same and are equally feasible. What option produces the most achievement? And, how could this be decided?

To assess the relative merits of options 1-4 we need to know the time scales of such learning events as forgetting, fatigue, boredom, and start up and wind down. If the time scale of "warming up" to school is of the order of a day (e.g. blue Mondays) then option 2 would be undesirable because most of the time would be spent in warming up and not in performing. If the characteristic time of "winding down" is four days, then option 4

would be desirable because it would eliminate Fridays. Option 3 might be attractive if time to forgetting were small, that is, if a constant stimulus to learning were required. Option 1 would be attractive only if this time to forgetting were extremely long. Otherwise, the amount of instruction retained would diminish appreciably over the long span of time completely out of school

Although we have no data on the time scales of any of these learning events to make such judgments, it seems reasonable that option 1 would be the worst choice from the view of maximizing educational output, if for no other reason than learning requires frequent reinforcing. There is some evidence that achievement declines over the summer recess suggesting that forgetting effects occur.[1] Moreover, these effects are appreciably greater for children in disadvantaged home environments than for children who presumably receive greater learning stimulus during the out of school period. Unfortunately, option 1 may be the only viable political choice in face of the demands from teacher's unions, working parents and forces of tradition.

Another example where characteristic times should prove valuable is in decisions about what types of curricula can best be taught intensively. Most students study courses concurrently, for example they spend their day studying math, social studies, English and French. A few schools have abandoned the concurrent plan and instead teach a single subject at one time. A familiar example of such intensive education is the Berlitz approach to studying foreign language. Now the question arises whether intensive education is a more efficient way of packaging instruction and if so for what kinds of subject matter.[2] The crucial consideration of

characteristic times here is the time to boredom or fatigue vs. the time to forgetting. Presumably the efficacy of this teaching approach is based on the assumption that minimizing the time to forgetting is very important. Whether the student's learning efficiency can be sustained for a given curricula depends however upon the relative sizes of time to boredome and time to forgetting.

The notion of characteristic times is also useful in deciding the optimum size of classroom for particular mixes of students. Suppose that the frequency of interruptions are positively related to class size, one would guess that for a fixed teacher/pupil ratio, it would be more productive to have smaller classes for students with long recovery times and larger classes for students with short recovery times.

We have described several examples in which a consideration of the characteristic time of the various learning events would provide a means for making a rational, educationally defensible choice. This same notion of characteristic times could be used to determine whether a school day of four hours or six hours might be optimum for instructional purposes, or whether a lunch break of one hour or one-half hour is a better scheduling of time. In all cases whether the unit of time is in days, seconds, hours or years we see that knowledge of the time scales can help determine the appropriate sequencing to maximize learning for a given duration of time.

These examples are suggestive of the variety of educational decisions which might be informed by attention to the characteristic times of episodes comprising a learning sequence. Some of the time scales are individual-curriculum dependent. Other time scales such as ones relating to interruptions are more classroom-curriculum dependent and are likely to be

time scales over which we have some control. By being able to identify and estimate the characteristic time of the uncontrollable factors, one can hope to improve the process of learning by appropriately setting the controllable ones.

Notes for Section 5

1. For evidence on this point see Murnane, p. 88 and also the study by Hayes and Grether (1969).
2. Few studies have examined the effects of intensive education. Powell (1976) presents a brief summary of research in this area.

6. Summary

This paper has formulated a model of teacher/learner/task involvement with these key features:

1. Learning is a dynamic process involving both a teacher and a learner in a learning task.
2. Teaching rate and student efficiency vary in time due to the nature of the learning task, the extent of the discrepancy between teacher's expectation and student's actual learning, and the way the instructional time is packaged.

The model as presented is not claimed to be an accurate mirror of how teachers and students behave in an actual classroom. It is, of course, an idealized version of what we select to see in some portion of the school day. However, the model does incorporate several real features of the learning setting. No one can deny that teachers have interruptions, become bored or occasionally teach faster than their students can grasp. Nor can anyone doubt that students are sometimes distracted, keenly interested or immensely bored by a learning setting. That is, the model incorporates realistic happenings into a hypothetical learning situation. What is interesting, of course, are the dramatic effects on achievement which we obtained from using even such a rudimentary model. To recapitulate, the simulation showed that:

1) Slower students, without extra time and help, can not keep up with the teacher and most likely will at some point have their learning efficiency so reduced that as the rest of the class progresses, they will fall farther and farther behind.
2) Faster students, who easily keep pace with the teacher and learn at a rate faster than expected will only get some fraction ahead because their learning is dependent upon the teacher.

3) The teaching strategy which maximizes average classroom achievement depends upon the degree of structure of the curriculum
   a) For highly structured curricula, the maximum is produced when the teaching rate is below the classroom ability level.
   b) For less structured curricula, the maximum is produced when the teaching rate is above the classroom ability level.
4) The teaching strategy which maximizes the classroom average is not necessarily the same as the one which assures the attainment of a minimum standard.
5) The teaching strategy for maximizing the classroom average or for assuring the attainment of a minimum standard is modified markedly by the incorporation of interruptions.

The usefulness of this model for a study of educational time use is centered around two observations.

1) Pacing differences, transient effects, packaging effects and task structure can all be characterized by their time scales.
2) Knowledge of the relative magnitude of the time scales of these factors is required to make decisions about optimum ways to organize instructional time.

Discussion

The view of learning and time put forth in this paper is intended to stimulate thought on theoretical and practical issues of how to organize instruction.

1. The model conceptualizes learning as a process which takes place in time and whose parameters can be expressed in terms of time.

The basic feature of our view is that the factors which determine the amount of learning can be expressed in terms of time. The difference between what the teacher expects and what the student knows can be expressed as the amount of time it would take him to catch up. The degree of structure of the curriculum can be expressed by the amount of time it takes for learning efficiency to be impaired. Characteristics of the learner can be incorporated by determining the amount of time it takes the student to learn a particular task. Teaching relevant characteristics can be expressed by the amount of time it takes to present/communicate a given task. Transient effects such as boredom, fatigue, keen interest, and interruptions can be expressed by the amount of time they take up and by the amount of time required to recover from them. Thus the events and factors which affect learning can be expressed in the same metric--the amount of time required.

2. The model suggests an alternate way to assess the effects of time and other factors on learning. We proposed a dynamic version of the learning process whose formulation may be useful in analyzing data from real schools as well as from simulated ones as we have done here. This formulation of learning as a dynamic process appears to be an appropriate, albeit infrequently used, perspective. A notable exception to this is a paper by Sorenson and Hallinan (1977) which examines schooling effects using a differential equations approach. The methodology of such approaches is discussed also by Coleman (1968).

3. The model suggests additional research topics. The usefulness of the model for addressing some practical and researchable issues concerning time allocation and availability in schools was only briefly discussed in section 5. We now sketch some additional topics.

a. Teaching characteristics:

1) What are the consequences for average achievement and for the distribution of achievement of a teaching strategy which

a) Keeps the average distance between teacher expectations and student knowledge a constant?

b) Keeps the difference between the slowest student and the teacher expectations a constant?

c) Keeps the difference between the fastest student and teacher expectations a constant?

2) What are the learning consequences of different grouping arrangements of students reflecting differing utilization and intensity of teacher time including

a) Whole group instruction (high pupil/teacher ratio for long durations of teacher-student contact)

b) Small group instruction with supervised seatwork (low pupil/teacher ratio for short durations of teacher-student contact).

3) What are the learning consequences of utilizing instructional time in the following ways

a) Teaching subjects intensively vs. concurrently (successive intervals of long duration that concentrate

on a single subject vs. short periods for several subjects during each instructional interval).

b. Learning and learner characteristics:

1) What are the correlates of time taken to reach a given performance level?

2) What are the learning consequences of evaluating individuals by their time to completion as opposed to their degree of completion at some fixed time?

3) What are the implications in terms of educational opportunity and equity of utilizing time to completion as an evaluative characteristic?

4) How do various teaching strategies (e.g. suggested in "a" above) promote different uses of outside of school time? How do these usages affect student efficiency?

c. Task structure

1) How can the degree of hierarchy of a subject be determined?

2) What other features of task structure besides its cumulativeness influence student efficiency?

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